SURFACE PLASMON-ENHANCED PHOTOVOLTAIC DEVICE

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to U.S. Provisional Patent Application No. 60/950,557, titled SURFACE PLASMON-ENHANCED PHOTOVOLTAIC DEVICE, filed Jul. 18, 2007, the disclosure of which is incorporated herein by reference in its entirety and for all purposes.

STATEMENT OF GOVERNMENTAL SUPPORT

[0002] The invention described and claimed herein was made at least in part utilizing funds supplied by the U.S. Department of Energy under Contract No. DE-AC02-05CH11231. The Government has certain rights in this invention.

BACKGROUND OF THE INVENTION

[0003] Solar energy is clean, abundant, widespread and renewable. Various technologies exist for capturing solar energy, concentrating it, storing it, and converting it into other useful forms of energy. Solar energy technologies have great potential benefit in that they can diversify energy supply, reduce dependence on fossil fuels, offset greenhouse gas emissions and improve air quality.

[0004] Edmond Becquerel first discovered the photovoltaic effect in 1839. He found that certain materials produced a small amount of electric current when exposed to sunlight. For long time the study of photovoltaics (PV) remained a curiosity until Bell Labs developed the first crystalline silicon photovoltaic cell with a conversion efficiency of about 4% in 1954. The first major commercial push for photovoltaics came from the space industry for the use in satellites. However, the high cost of these devices prevented large-scale commercialization for many years. Substantial government and industry research investments into photovoltaics as a general energy source did not occur until the energy crisis in the 1970s. At present, a broad range of homojunction, heterojunction p-i-n and n-i-p, and multijunction semiconductor devices exist that offer up to 50% total conversion efficiency.

[0005] In the last twenty-five years, the cost of PV has come down by several orders of magnitude. Unfortunately, about half the cost of a PV system remains in the PV module itself.

SUMMARY OF THE INVENTION

[0006] The present invention provides innovative photovoltaic devices driven by intense photoemission of "hot" electrons from a suitable nanostructured metal. The metal should be an electron source with surface plasmon resonance within the visible and near-visible spectrum range (near IR to near UV (about 300 to 1000 nm)). Suitable metals include silver, gold, copper and alloys of silver, gold and copper with each other. Silver is particularly preferred for its advantageous opto-electronic properties in the near UV and visible spectrum range, relatively low cost, and simplicity of processing.

[0007] Illumination of nanostructured Ag (e.g., particle size about 1-50 nm) creates multiply excited surface plasmons in Ag nanoparticles. The surface plasmon in nanoparticles is also known as the Mie plasmon or the surface plasmon polariton (SPP) that corresponds to the collective motion of the electrons coupled directly to a transverse light field. The resonant multiple excitation of the surface plasmon resonance in Ag nanoparticles leads to a strong enhancement of the photoemission yield. A substantial portion of the surface plasmons in Ag nanoparticles transfer their total excitation energy to a single photoelectron. The decay of the excited plasmons leads to the generation of hot electrons, which carry the total energy of the collective mode, i.e., up to 7 eV. The resulting hot electrons can travel in excess of the approximately 20 nm electron mean free path in silver, and surmount a Schottky barrier formed at the junction of silver and an underlying semiconductor (e.g., TiO_2). If the electron energy is larger than the Schottky barrier, the excited electron can escape from the Ag nanoparticle into the semiconductor conduction band. By collecting photoexcited hot electrons in the semiconductor layer a steady-state electron flow is produced upon continuous irradiation of a silver electrode with visible and near UV light.

[0008] In one aspect, the invention relates to an electronic device comprising a metal electron source layer having a nanostructured metal surface with a surface plasmon resonance within the visible and near-visible spectrum range; a semiconductor layer in contact with the metal electron source layer, wherein the metal electron source layer and the semiconductor layer form an interface that is a Schottky barrier; and an electrode layer in contact with the semiconductor layer, wherein the electrode layer forms an ohmic contact to the semiconductor layer.

[0009] Associated photovoltaic devices and methods of their making are also provided.

[0010] The invention provides an effective, low-cost PV device that is readily manufactured by semiconductor device fabrication techniques readily adaptable for the purpose by those skilled in the art given the description provided herein.

[0011] These and other aspects of the present invention are described in more detail in the description that follows.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] The foregoing aspects and others will be readily appreciated by the skilled artisan from the following description of illustrative embodiments when read in conjunction with the accompanying drawings.

[0013] FIG. **1** is a cross section schematic diagram showing the basic components of a metal/semiconductor Schottky diode photovoltaic cell, according to an embodiment of the invention.

[0014] FIG. **2** is a plot of photoemission quantum yield as a function of wavelength of incident light for polished and roughened silver surfaces.

[0015] FIG. **3** is a cross section schematic diagram showing a Ag/n-TiO_2 Schottky diode photovoltaic cell device, according to an embodiment of the invention.

DETAILED DESCRIPTION OF SPECIFIC EMBODIMENTS

[0016] Reference will now be made in detail to specific embodiments of the invention. Examples of the specific embodiments are illustrated in the accompanying drawings. While the invention will be described in conjunction with these specific embodiments, it will be understood that it is not intended to limit the invention to such specific embodiments. On the contrary, it is intended to cover alternatives, modifications, and equivalents as may be included within the spirit and scope of the invention as defined by the appended claims.